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TECHNICAL REPORT ECOM-01377-2

BALLISTIC WINDS STUDY

QUARTERLY REPORT NO. 2

By

FREDERICK P. OSTBY, JR.

MARCH 1966

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

CONTRACT NO. DA 28-043 AMC-01377(E)

THE TRAVELERS RESEARCH CENTER, INC.
250 CONSTITUTION PLAZA, HARTFORD, CONNECTICUT 06103

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THE TRAVELERS RESEARCH CENTER, INC.
250 Constitution Plaza Hartford, Connecticut 06103

For

U.S. ARMY ELECTRONICS COMMAND, FORT MONMOUTH, N.J.

ABSTRACT

Subjective analyses were made of ballistic winds at two-hourly intervals for five time periods over a region of southeastern Arizona in the vicinity of Ft. Hauchuca. One procedure was to analyze the winds (integrated from the surface to 8000 meters) at the twelve observational sites without regard to the changing radiosonde locations during their flight. A second procedure was to account for the fact that the geographical coordinates of the observation are a function of height by plotting the meteorological information at the locations of the radiosonde for the various altitudes of interest. These analyses are presented and compared. Significant differences in ballistic wind occur when the horizontal gradients of the wind components are large and the radiosonde balloons are displaced a considerable distance.

Modifications in a preprocessing computer program are being made to error check the basic meteorological data and make the necessary corrections. This program will put the data in a form suitable for the subsequent objective analysis programs.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

The purpose of Contract DA 28-043 AMC-01377(E) is to develop an improved automated technique for computing ballistic winds, temperature and density in mountainous terrain.

Work in the second quarter centered around the preprocessing and objective analysis programs described in the previous quarterly report. The preprocessing program has been completed and some initial production running of the basic data has been performed. In carrying out this phase of the processing, certain problems were uncovered which required some minor modifications to be made to the preprocessing program. The details of these problems and modifications are contained in Section 3.0. The programming of the objective analysis technique, CRAM (Conditional Relaxation Analysis Method), should be completed shortly after the entire data sample has been successfully run through the preprocessor.

Some preliminary hand analyses of a portion of the basic data were performed while awaiting the completion of the computer programs. These analyses are discussed in Section 2.0.

2.0 ANALYSIS EXAMPLES

2.1 Background

In computing ballistic corrections, the customary procedure is to measure upper-air parameters by radiosonde for the purpose of estimating the effects of wind, temperature, and density on a projectile during its flight. For computational purposes the atmosphere is divided into various zones, and the density, temperature and average wind velocity are determined for each zone. These zone values are then weighted according to specified zone weighting factors, and mean weighted quantities are established. In the case of wind, this quantity is called the ballistic wind and is defined as a wind of assumed constant speed and direction which would have the same total effect on a projectile during its flight as the varying winds actually encountered. The weighting factors used have been developed by ballisticians. The weighting factors for wind for surface-to-surface firing with a trajectory whose maximum ordinate is 8000 meters is shown in Table 2-1. Also shown is the atmospheric zone structure up to 8000 meters.

TABLE 2-1
ZONE STRUCTURE AND WIND WEIGHTING FACTORS FOR BALLISTIC WIND COMPUTATIONS (maximum ordinate 8000 meters)

Zone	Height (meters)		Weighting factor*
	Base	Top	
1	Surface	200	.01
2	200	500	0.02
3	500	1000	0.02
4	1000	1500	0.04
5	1500	2000	0.03
6	2000	3000	0.07
7	3000	4000	0.08
8	4000	5000	0.09
9	5000	6000	0.09
10	6000	8000	0.55

*From FM 6-16, Tables for Artillery Meteorology

Ballistic winds are generally expressed in range and cross-wind components. Ballistic density and temperature are expressed in percent departure from the ICAO standard atmosphere. Unit corrections (per one percent variation from standard for temperature and density or per one knot of range wind and cross wind) are extracted from appropriate firing tables and applied to the determined meteorological effects to arrive at the required ballistic corrections. More detailed information on ballistic meteorology may be found in FM 6-16, Artillery Meteorology.

The problems under study in this contract are concerned with computing ballistic quantities from a closely spaced network of 12 upper-air stations in the Ft. Huachuca region of southeastern Arizona (see Fig. 2-1). Soundings were taken 5 times a day at two-hour intervals beginning at 0600 MST for even numbered days January 2—12, odd numbered days January 25—31, and even numbered days February 2—12, 1965. On several of these days, two 8-inch howitzers were fired at 1000 MST and 1400 MST at a pair of targets approximately 14.5 km east-northeast from the gun locations. The range of firing is shown as a line segment on Fig. 2-1 just north of Ft. Huachuca. The projectile impact locations from these firings are to be corrected using the ballistic quantities derived from the meteorological data in such a fashion as to give optimum results.

2.2 Manual Analysis Procedures

Ballistic wind components (u and v) may be computed at individual stations and then analyzed as one would analyze conventional meteorological parameters to yield so-called "map winds"*. This was done manually for the five time periods of one day of the data sample (25 January, 1965). These maps are shown in Figs. 2-2 through 2-6.

The analyses show a situation of strong westerly winds (large u-component, small v) over the analysis region. During the early part of the series (0600 MST and 0800 MST) the u-component shows a general increase from north to south. The trend, however, is for an increasing west to east gradient as the winds diminish over the western half so that by 1200 MST, the u-component in the eastern section is much larger than in the western section. The v-component shows a very small gradient over

*Use of Map Winds for Artillery Purposes—Part I, M. J. Lowenthal, Hdqts. Signal Corps Engineering Laboratories, Ft. Monmouth, 1953.

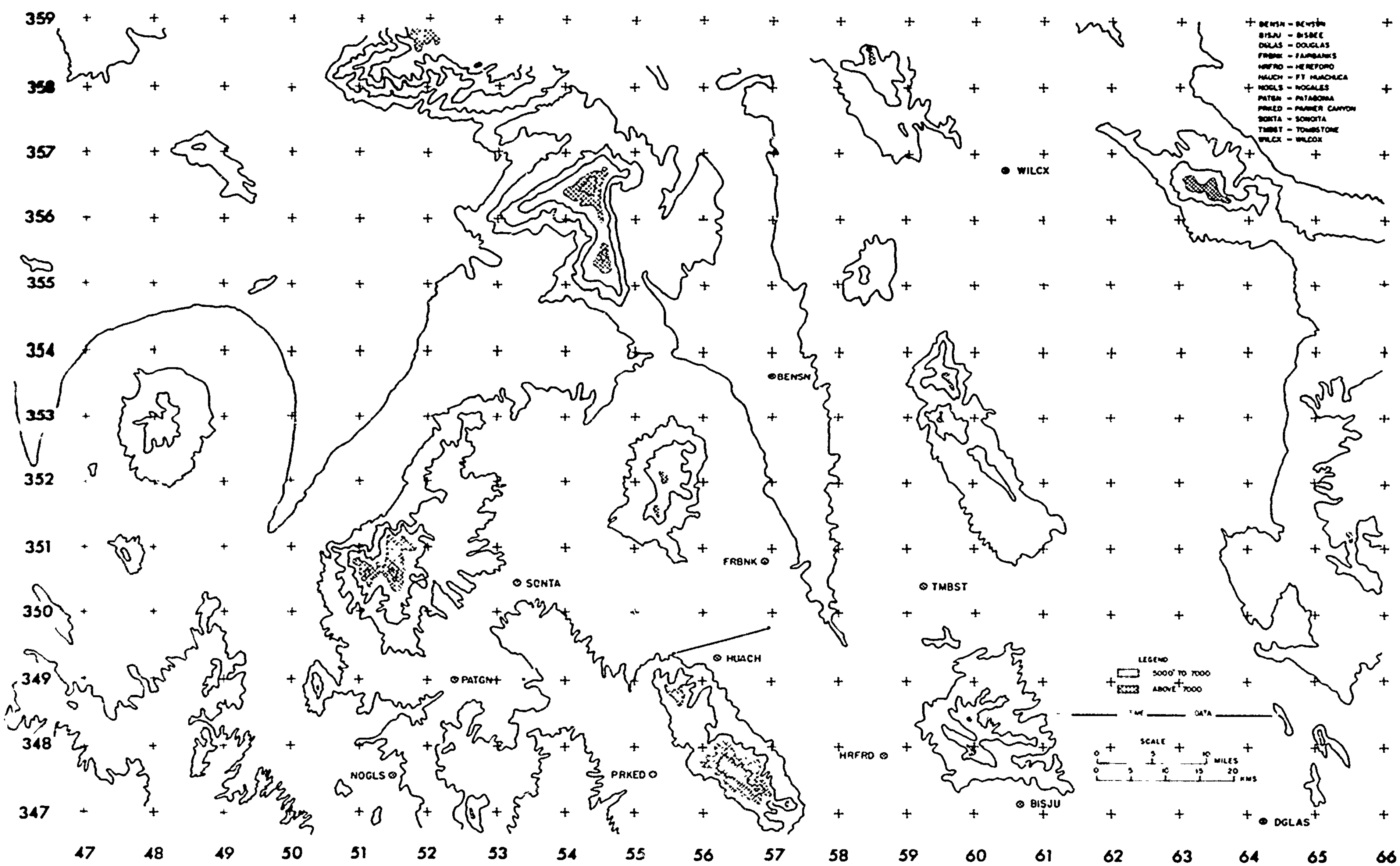

Fig. 2-1. Network of observing stations. Line segment indicates firing range. Grid interval is 10 km.

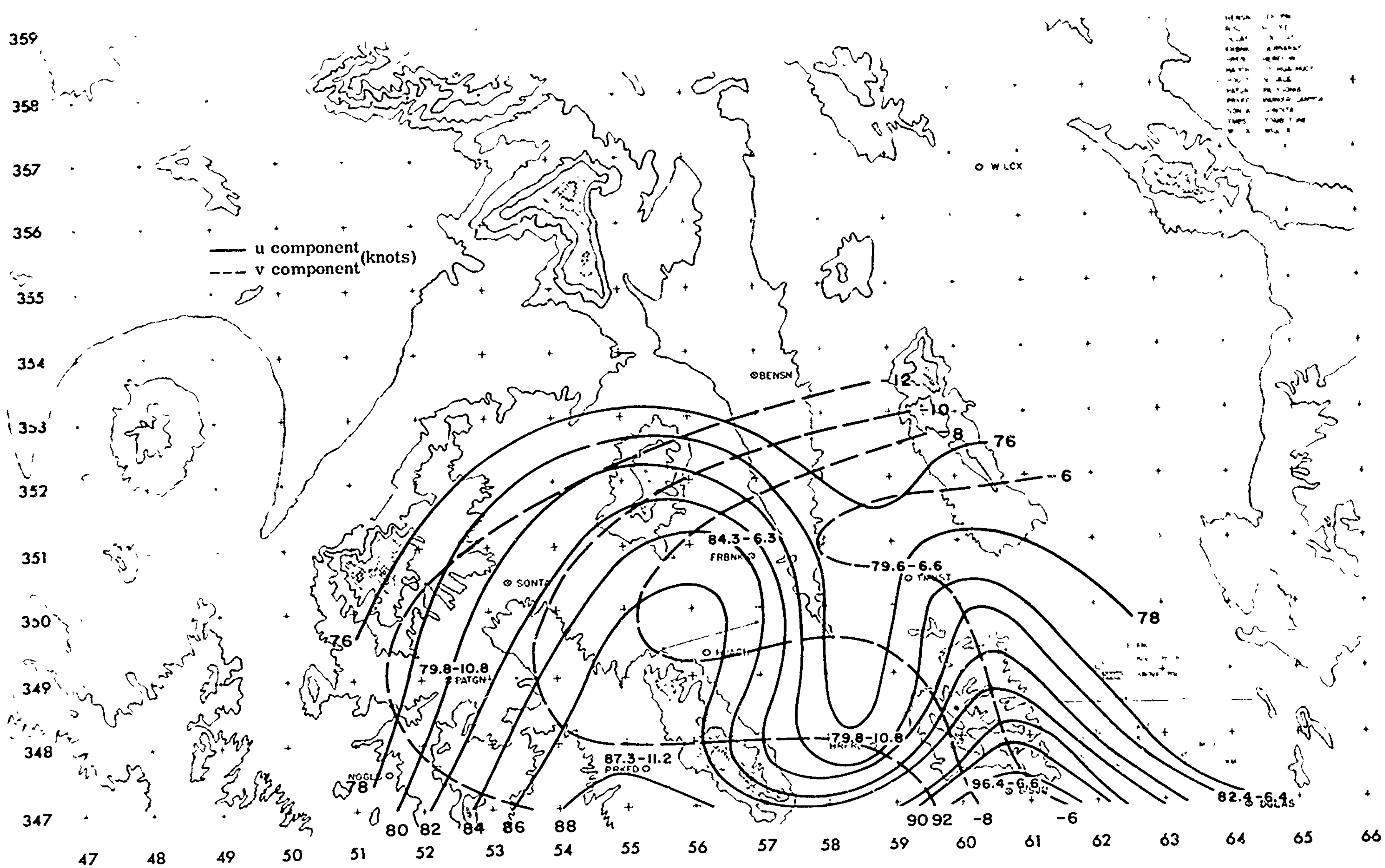

Fig. 2-2. Ballistic wind analysis (fixed stations) for 0600 MST, 25 January, 1965. Station plotting model consists of u component to the left and v component to the right.

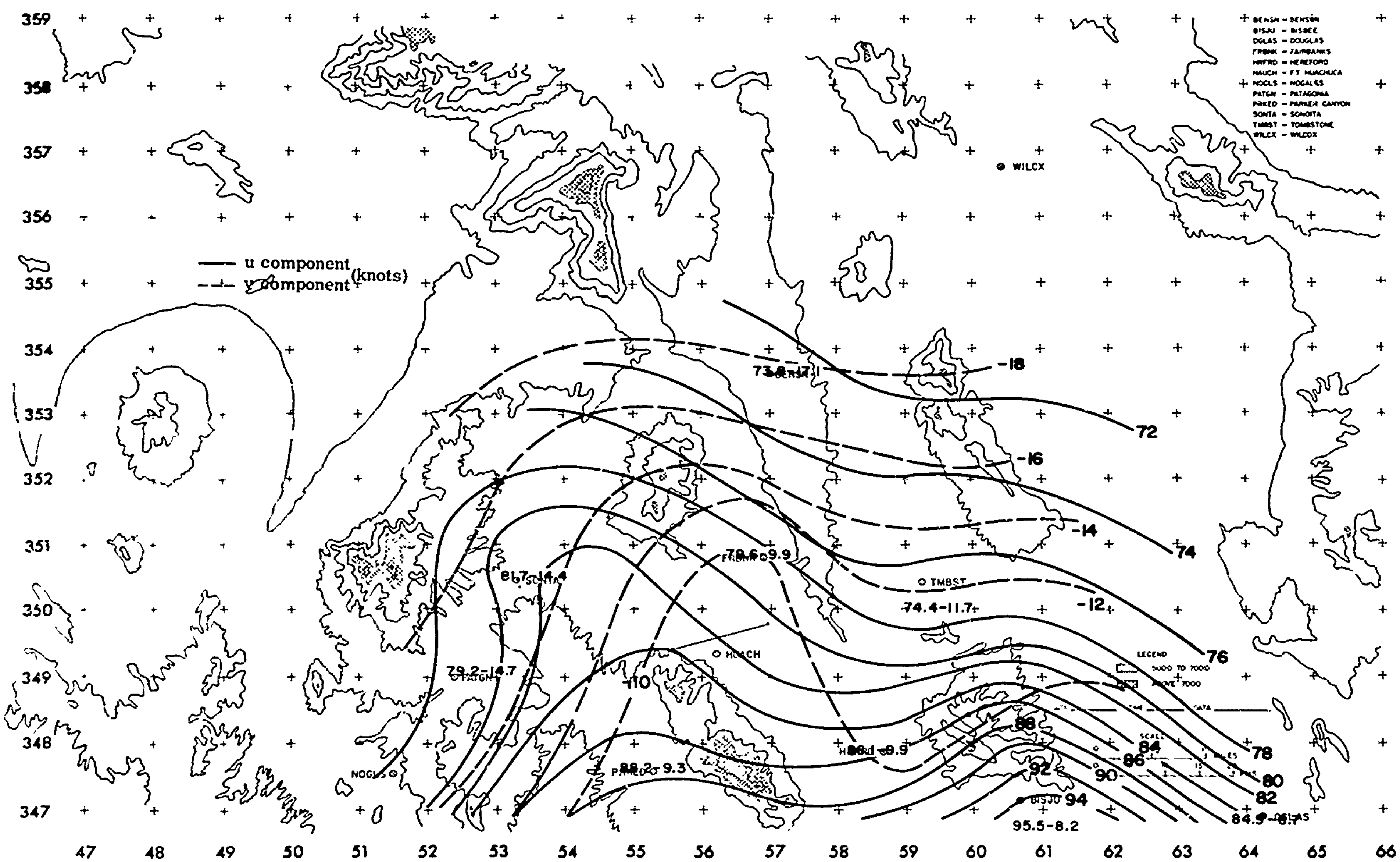

Fig. 2-3. Ballistic wind analysis (fixed stations) for 0800 MST, 25 January, 1965. Station plotting model consists of u component to the left and v component to the right.

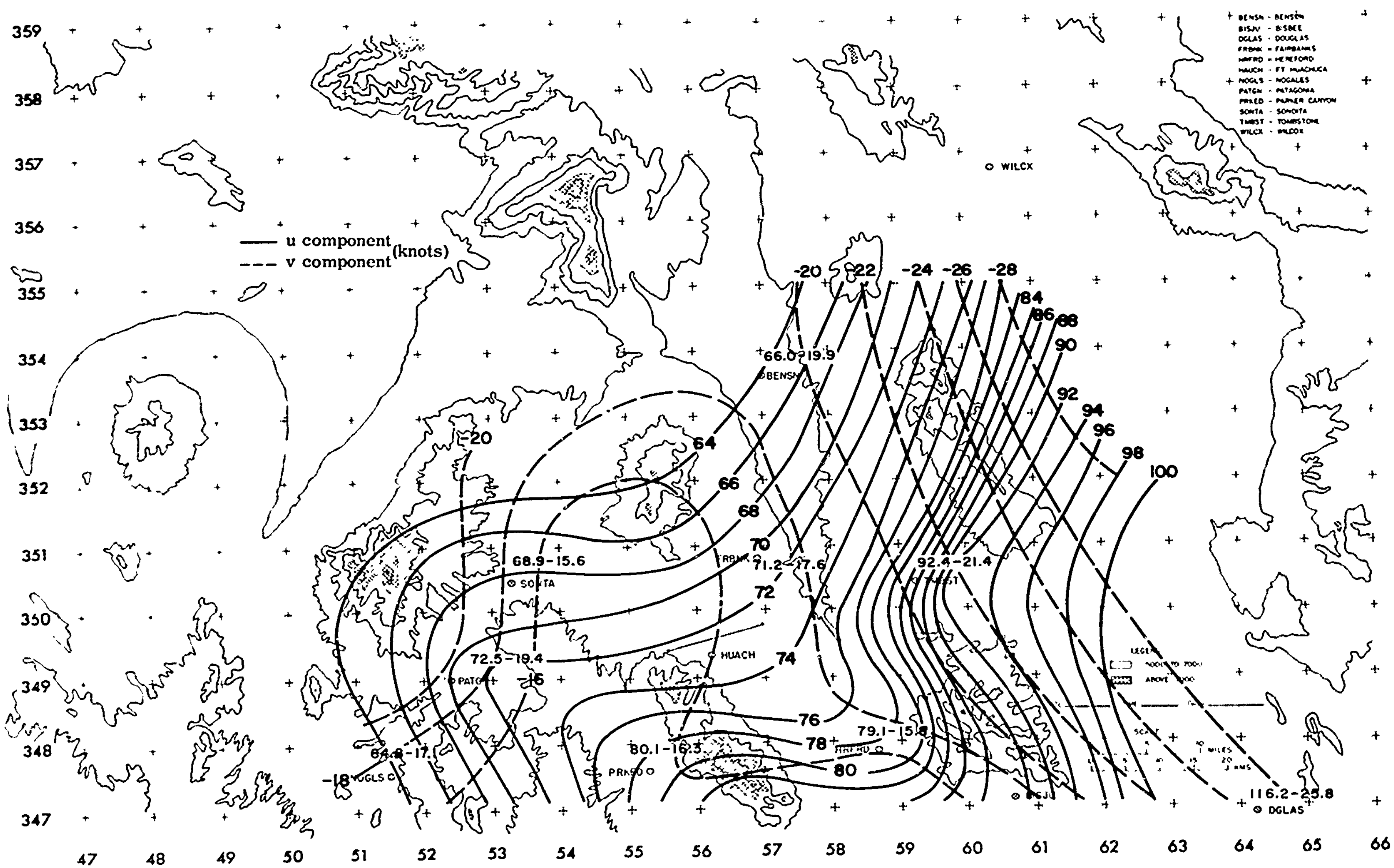

Fig. 2-4. Ballistic wind analysis (fixed stations) for 1000 MST, 25 January, 1965. Station plotting model consists of u component to the left and v component to the right.

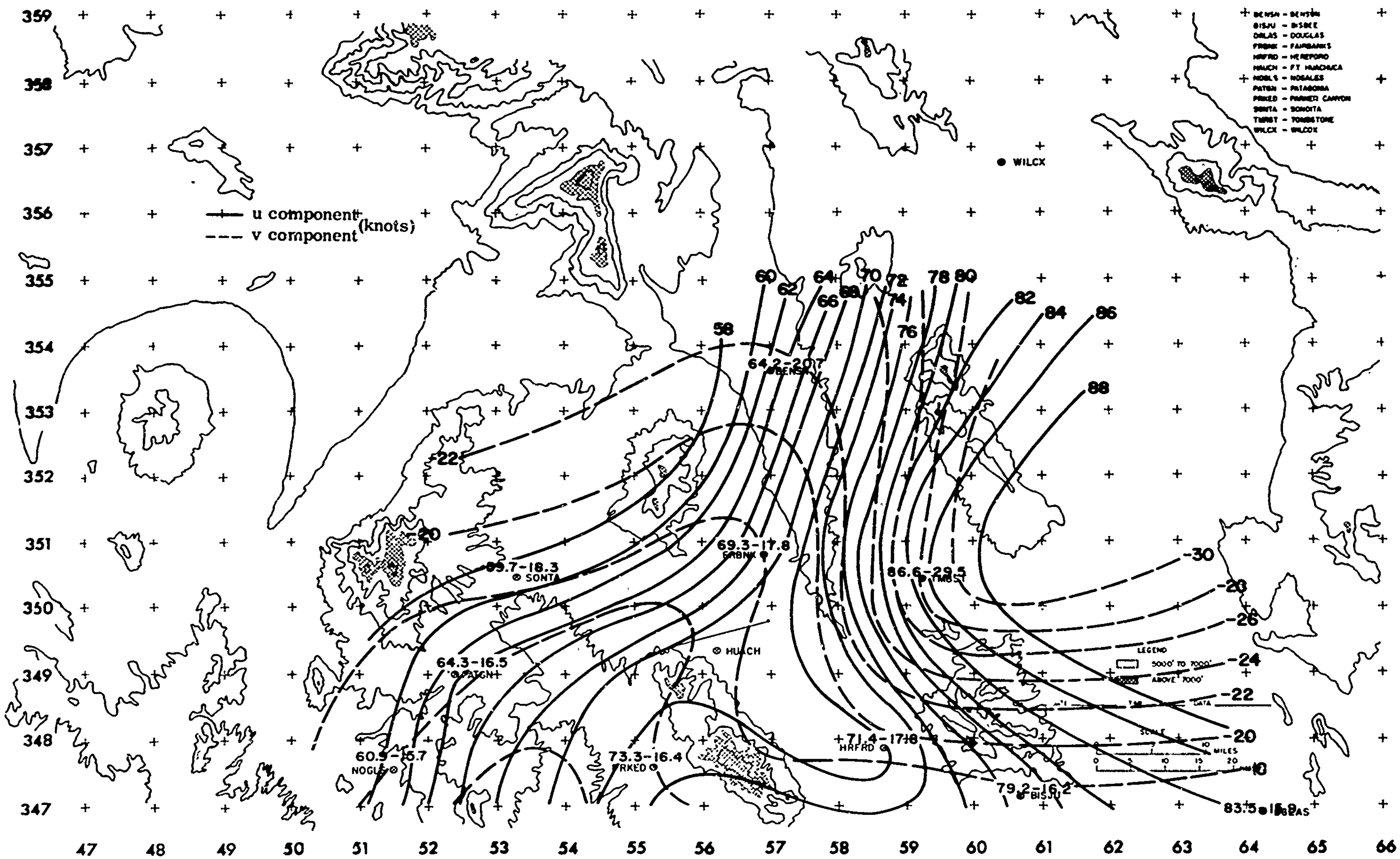

Fig. 2-5. Ballistic wind analysis (fixed stations) for 1200 MST, 25 January, 1965. Station plotting model consists of u component to the left and v component to the right.

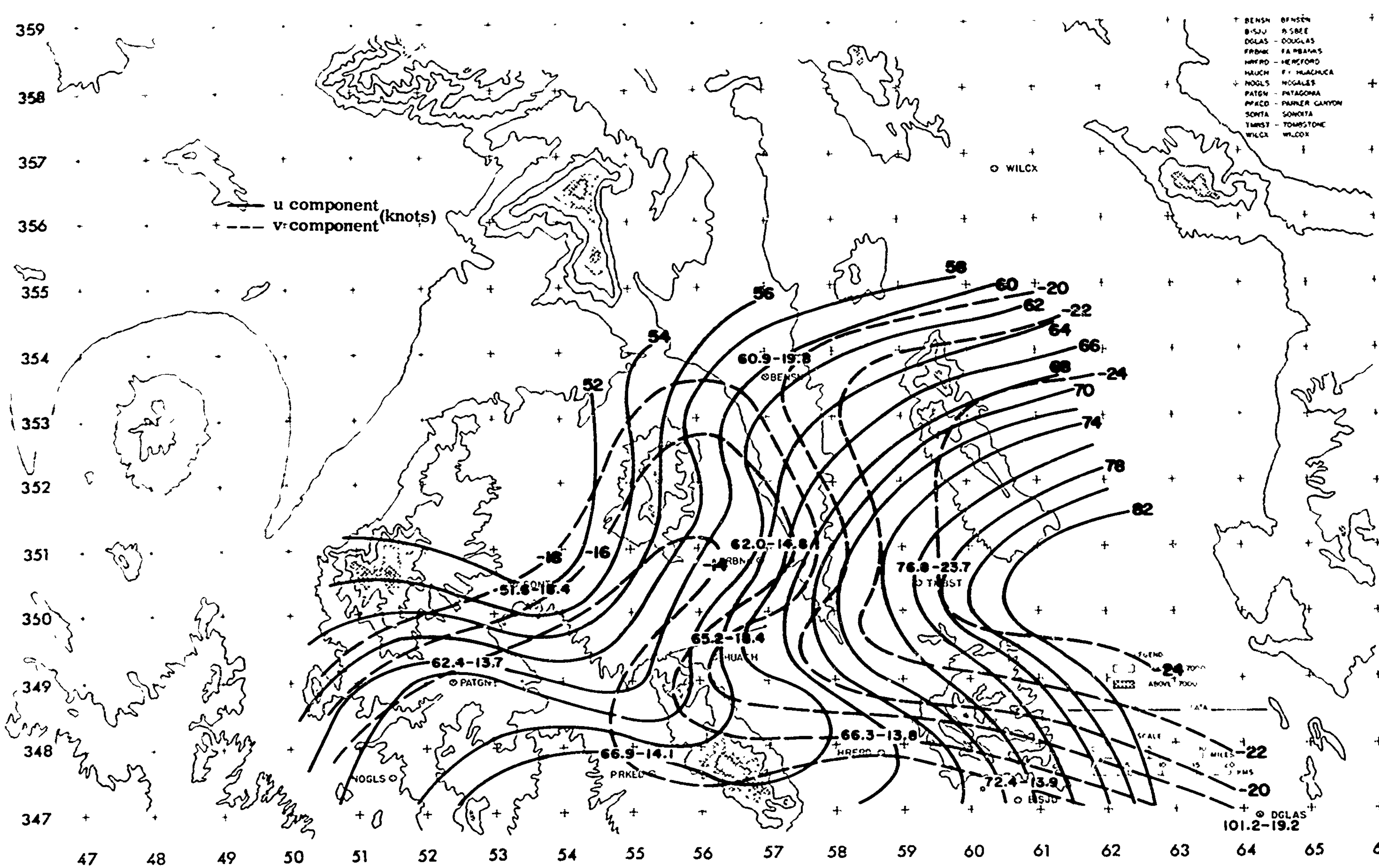

Fig. 2-6. Ballistic wind analysis (fixed stations) for 1400 MST, 25 January, 1965. Station plotting model consists of u component to the left and v component to the right.

the area initially, but strengthens with time as the winds over the eastern half veer toward the northwest.

In deriving these maps, the ballistic wind computed from a station's radiosonde ascent was plotted for analysis purposes at the station location regardless of where the balloon traveled during its ascent. An alternate analysis procedure is to take into account the balloon's drift when plotting the geographical location of the observation. Thus, an analysis is made for each of the individual zones based on the location of each balloon at the midpoint of the zone. For example, for zone 10, the observation point, instead of being the station location, is plotted as the radiosonde's location midway between 6000 and 8000 meters above the ground. In the case of strong winds, this difference can be several kilometers (around 50 km on 25 January, 1965), which is significant when compared to the average spacing of stations in the network. Examination of the wind weighting factors in Table 2-1 shows that the highest zone (zone 10), when the radiosonde is likely to be the farthest from the launch site, receives the greatest weight (55 percent). For this reason, one would expect this alternate analysis procedure to produce maps differing from the conventional "fixed-station" analyzed maps, with considerable difference for strong wind cases and little difference for light wind situations.

The January 25th situation was characterized by strong winds. The analyzed maps of ballistic winds based on the radiosonde locations for each zone are shown in Figs. 2-7 through 2-11. In general, the patterns for the u-component are similar to the fixed-station maps except that they are displaced to the east, which appears reasonable because the radiosonde displacement is to the east. Thus, instead of finding a u-component of around 92 knots in the vicinity of Tombstone at 1000 MST (Fig. 2-4), the analysis in Fig. 2-9 indicates a value of about 71 knots. At the same time, the differences between the v-component at that location are small. This holds true for the v-component.over most of the entire series because of the weak gradients present.

It is interesting to note the differences between the two analyses over the region where the artillery firings were conducted. Table 2-2 lists the values of u and v for the map series at the approximate midpoint of the artillery trajectories based on

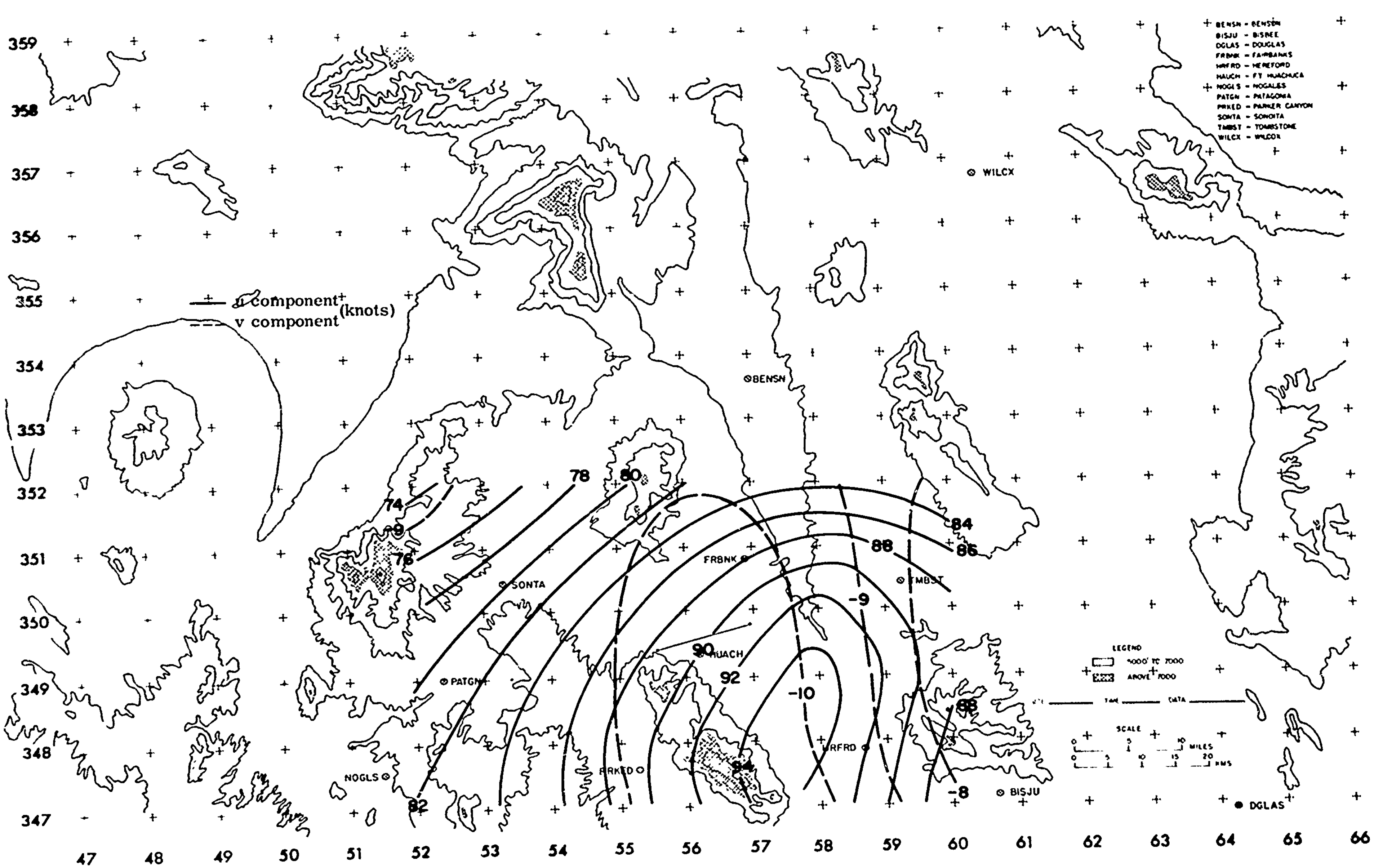

Fig. 2-7. Ballistic wind analysis (displaced stations) for 0600 MST, 25 January, 1965.

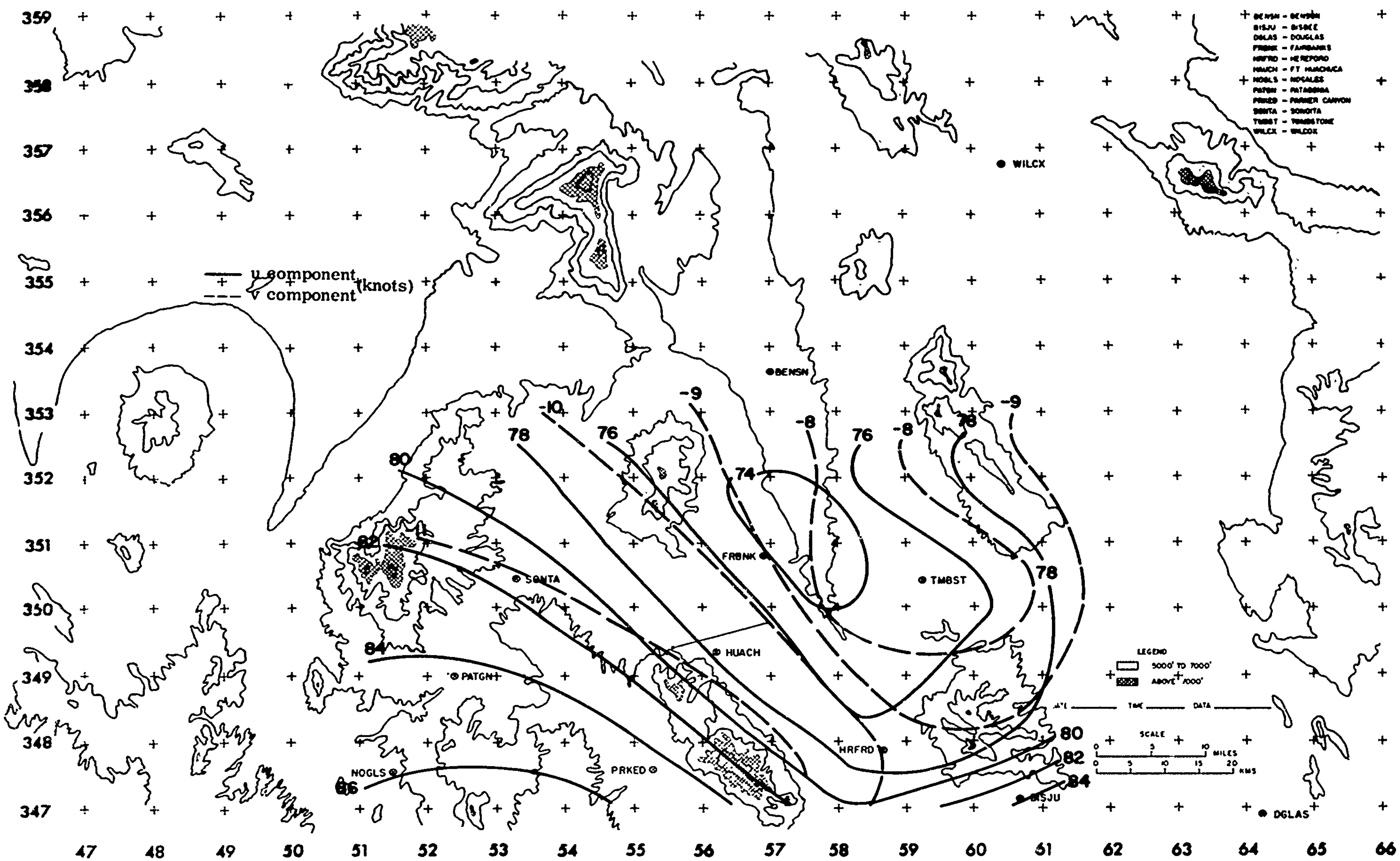

Fig. 2-8. Ballistic wind analysis (displaced stations) for 0800 MST, 25 January, 1965.

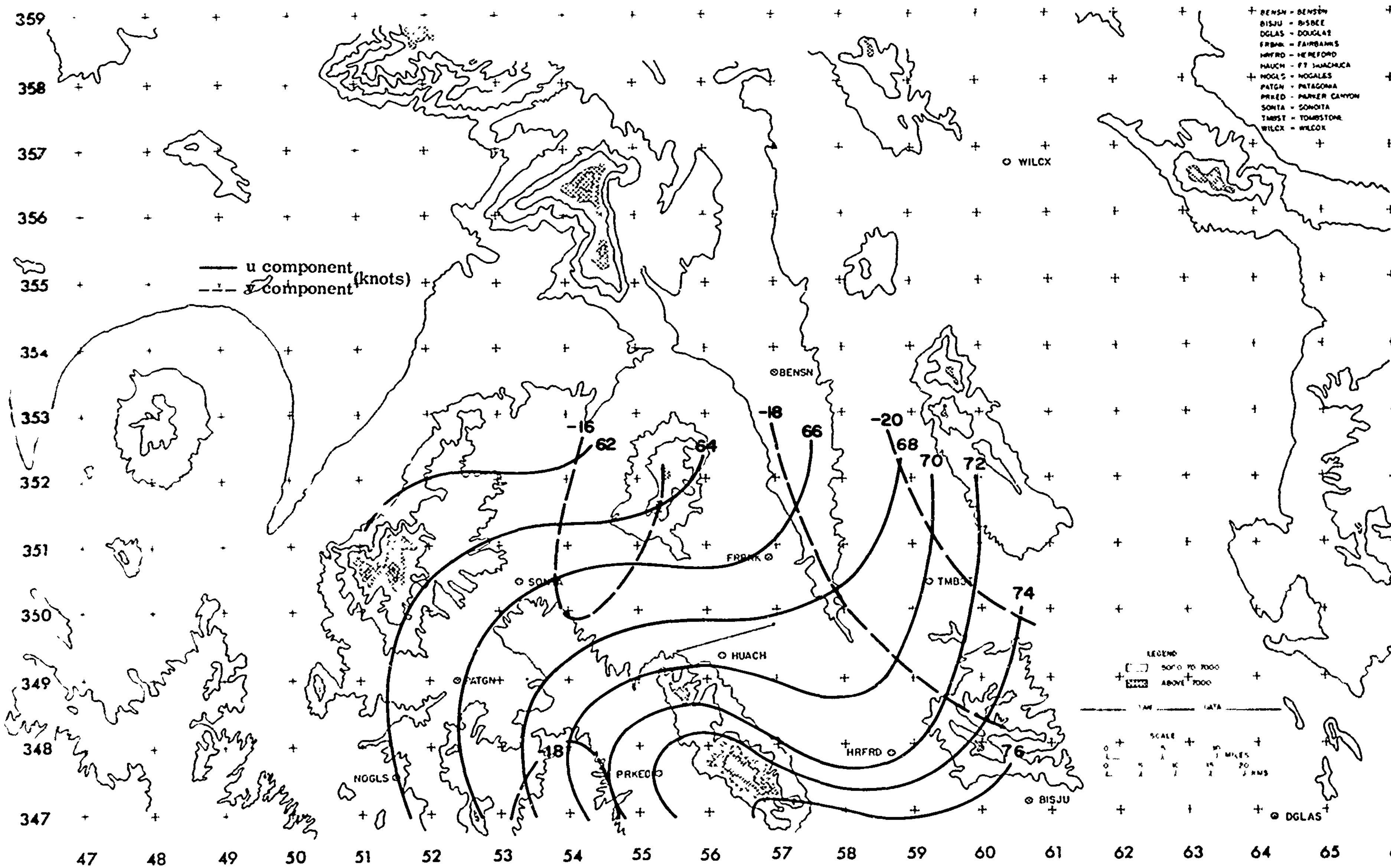

Fig. 2-9. Ballistic wind analysis (displaced stations) for 1000 MST, 25 January, 1965.

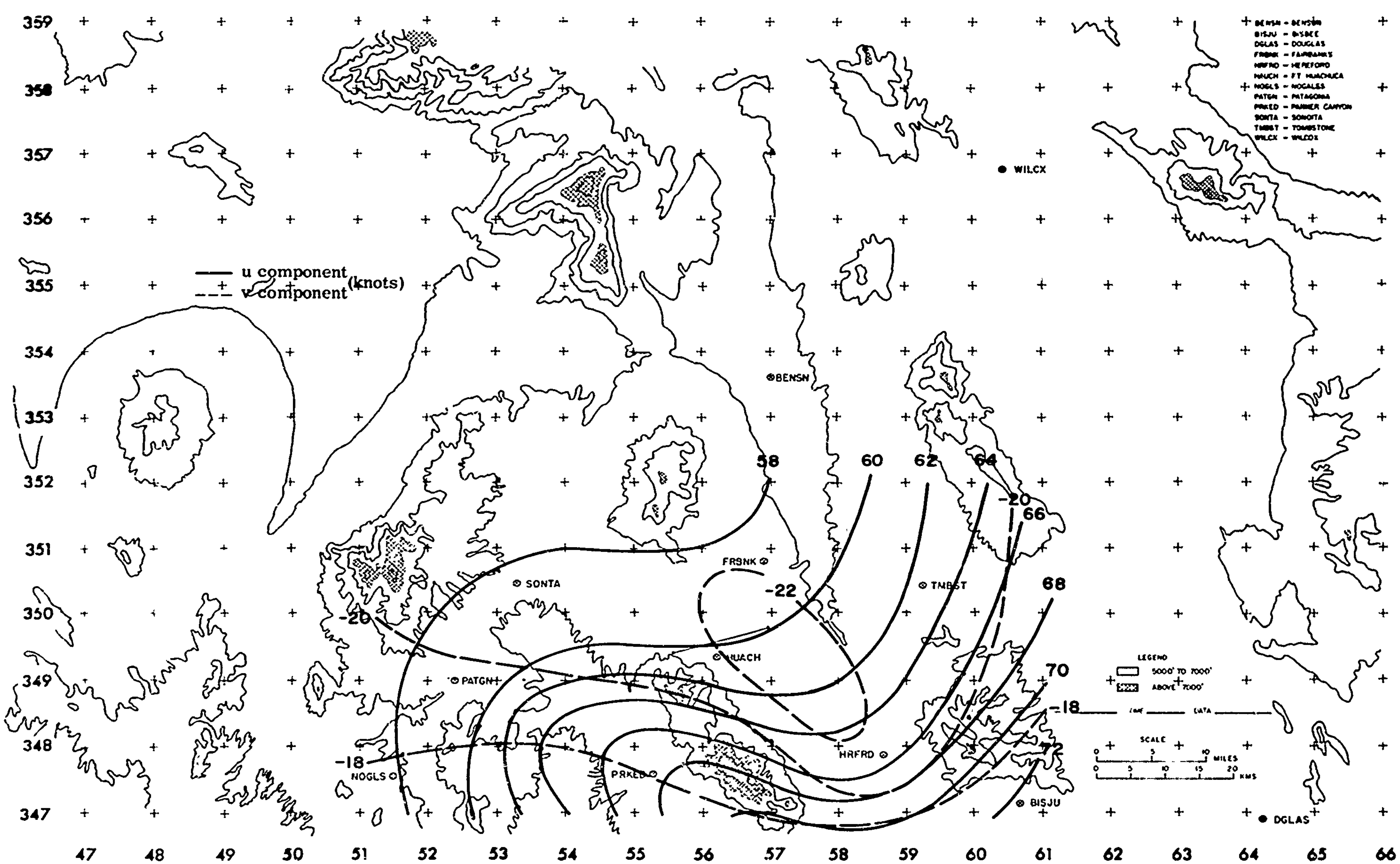

Fig. 2-10. Ballistic wind analysis (displaced stations) for 1200 MST, 25 January, 1965.

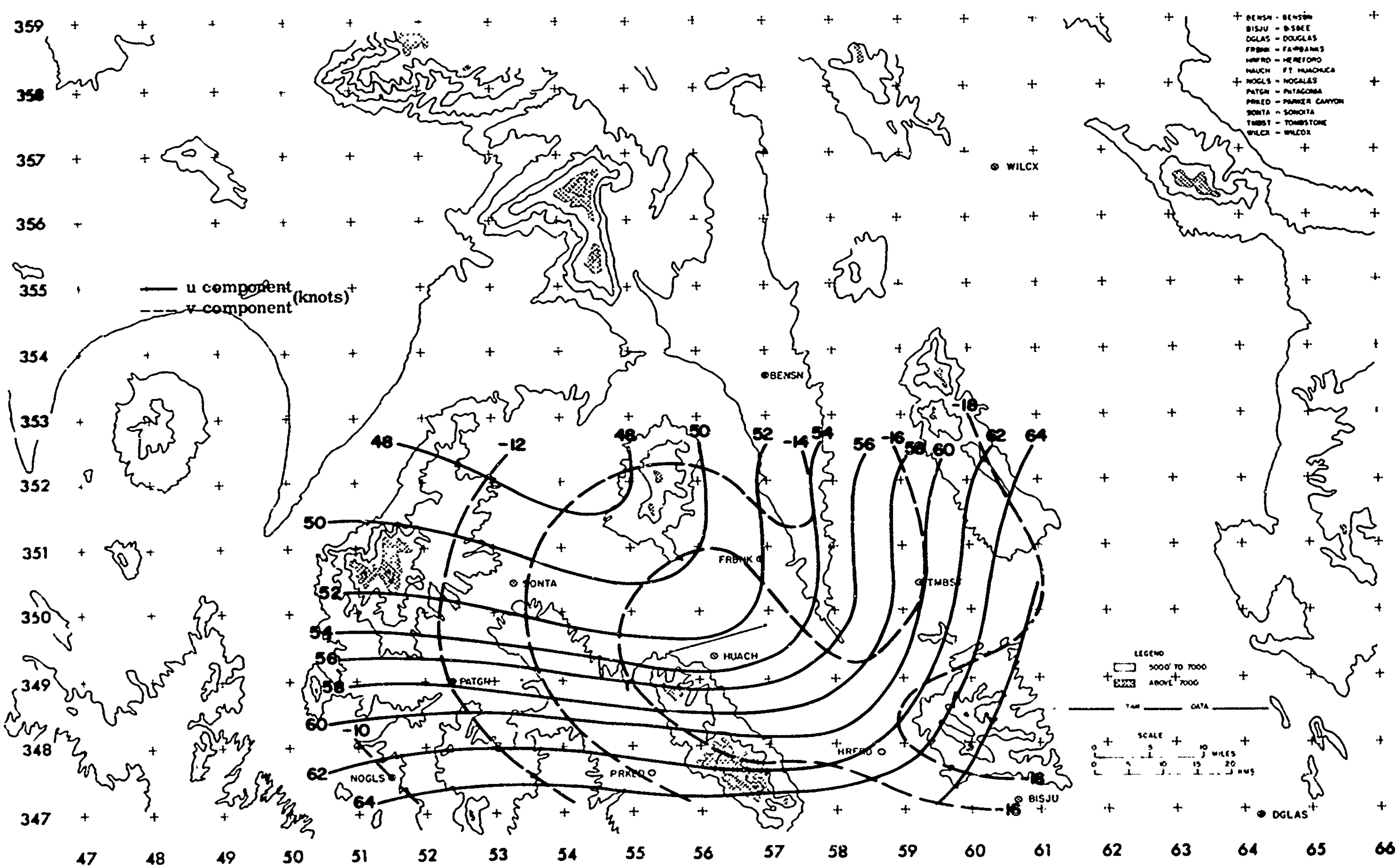

Fig. 2-11. Ballistic wind analysis (displaced stations) for 1400 MST, 25 January, 1965.

TABLE 2-2
COMPARISON OF BALLISTIC WIND COMPONENTS AT
MIDPOINT OF PROJECTILE TRAJECTORY
(A-analysis based on fixed stations, B-analysis based on radiosonde displacement)

Time (MST)	u-component (knots)		v-component (knots)	
	A	B	A	B
0600	86.2	89.7	-7.7	-10.5
0800	82.0	77.5	-9.2	-10.8
1000	72.8	69.2	-16.5	-16.7
1200	70.7	60.3	-17.4	-22.2
1400	64.8	52.2	-17.6	-17.5

the two analysis procedures. They are also shown graphically in Fig. 2-12. These differences are considerable when one considers that a deviation of one knot in range wind corresponds to a change of about 20 meters in range for the firing situation under investigation. The largest difference in the u-component occurs at 1400 MST (12.6 knots). This resolves into a difference in range wind of 12.1 knots or around 240 meters of range.

While these two analysis procedures will yield different results depending on the strength of the wind and the gradient of the parameter being analyzed, it remains to be demonstrated that the procedure of accounting for the radiosonde displacement will yield better results in terms of distance between projectile impact point and target location. This will be investigated further during the next work increment. Also, it should be noted that the analyzed maps presented in this report were prepared subjectively and, therefore, should be considered preliminary in nature.

In regard to predictability, it can be seen from Fig. 2-12 that reasonably good 2-hr forecasts of the u-component for the 1000 MST and 1400 MST firing times could be made by extrapolation of 2-hr changes in u-component at 0800 MST and 1200 MST from the displaced radiosonde analyses. Also, the observed 4-hr change at 1000 MST would have provided a good 4-hr forecast valid at the 1400 MST firing time. Extrapolation techniques for the v-component, however, do not work as well on this particular case.

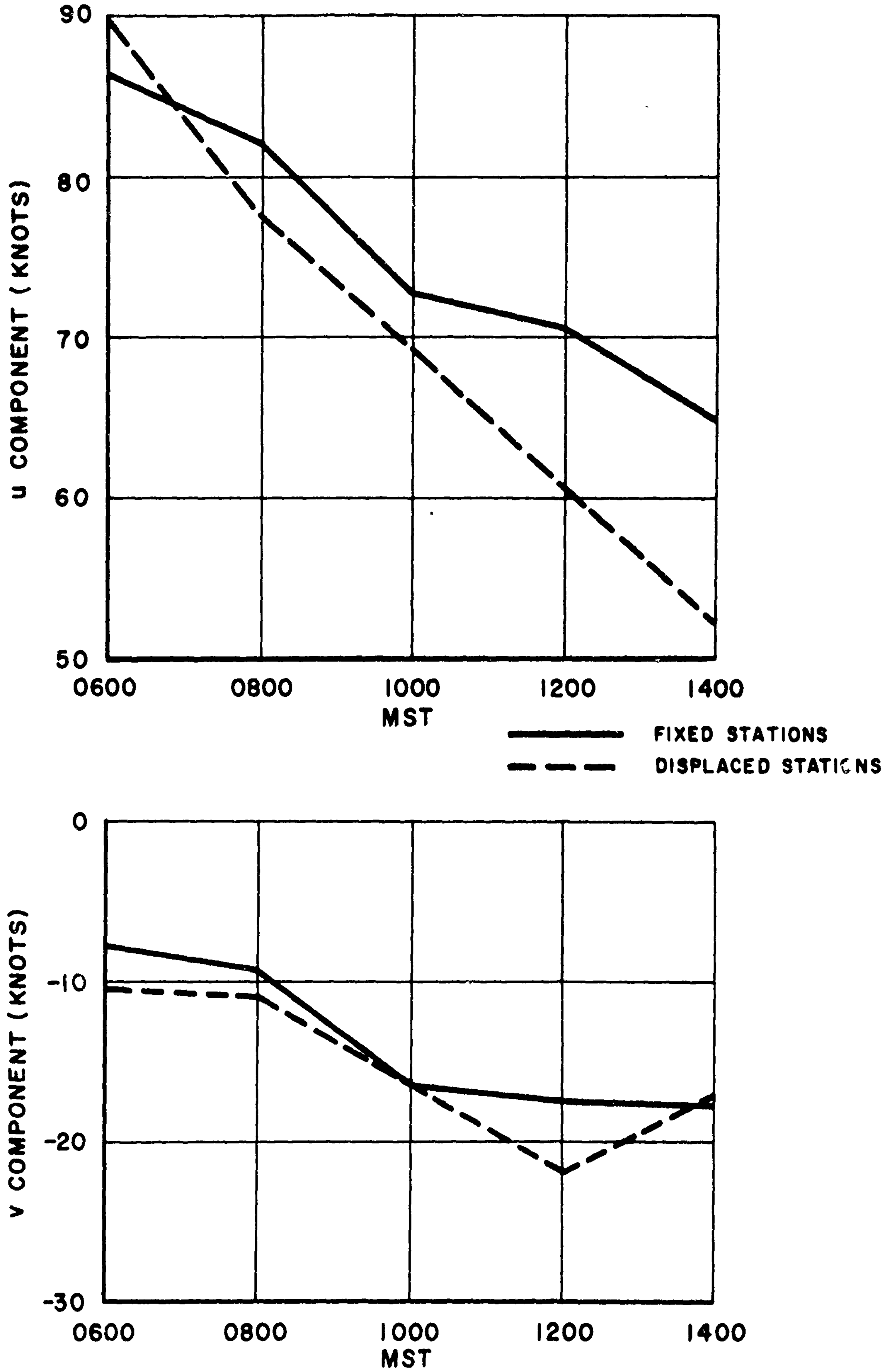

Fig. 2-12. Ballistic wind components (u and v) at the midpoint of the projectile trajectory for the five time periods of 25 January 1965.

3.0 PREPROCESSOR MODIFICATIONS

Certain errors were detected in the data when the preprocessor program was applied to the first of three magnetic tapes containing the basic meteorological data. There were generally four types of errors found that required resolution:

(a) Identification headings: Each station's report consists of four parts: significant level information; detailed wind information including displacement of the radiosonde; ballistic wind, temperature, and density information; and winds aloft data. Each part is headed by identifying information as to station name, time, date, and altitude. A few errors in these headings were noted and, depending on the circumstance, occasionally resulted in an incomplete program run. Because of the nonsystematic nature of these errors in time, date, etc., there was no way to modify the program to take them into account. Instead, a listing of headings had to be made and the proper corrections inserted where appropriate.

(b) Station altitude: There was a small number of occurrences in which the station's altitude was reported incorrectly. This type of error caused meteorological data to be assigned to the wrong heights. The preprocessing program has been modified to compare the station's altitude as reported with its known altitude. When it differs, the heights are then corrected by the program.

(c) Cards out of order: Meteorological information for each level or time was initially on punched cards before being read into magnetic tape prior to shipment to the contractor. Each level was represented by a separate card. Examination of some of the data indicated that a card, on rare occasion, was out of order. The preprocessor has been modified to check the time and/or level for this type of error and to print out such errors.

(d) Excessively-large numbers: A problem was found to occur when the radiosonde was displaced southward an excessive amount. When this displacement equalled or exceeded 100,000 meters, there was an insufficient number of characters in the card or tape format. This was reported on tape as an asterisk and the actual displacement was lost. However, it was found that when this happened the height of the radiosonde was much higher than the altitudes of interest to us. We are making note of these occurrences in the event they may be of interest to some other user of the data.

It should be emphasized that the number of errors found has been very small in comparison with the volume of data involved. The corrections are necessary for our work and may also be helpful to the sponsor for other uses of the data.

APPENDIX. CONSTRUCTION OF BALLISTIC WIND MAPS

A.1 Introduction

Construction of the ballistic wind maps is of necessity a subjective task. The isotachs may be drawn in more than one way using the given data. Furthermore, each map so constructed may be valid, in that the isotachs conform to the values of the ballistic wind at the station locations.

If a series of ballistic wind maps are drawn so that one has past history, another criterion becomes involved. Continuity between successive maps should be maintained. This will tend to reduce the number of acceptable charts, since many circulation problems cannot be followed from map to map.

It should be emphasized that far less is known of these ballistic charts than of common meteorological maps. There have been very few of these series constructed, and the predictability of the parameters has not been rigorously established. The principle of map continuity must, however, be maintained whenever possible.

Consequently, for this study, it might be necessary to re-analyze a map after a later one has been completed, especially if the two maps are widely divergent in the circulation patterns. This is especially true if the interval between maps is small, e.g., 2 hours, as in the present study, and wind components are large, giving rise to definite circulations.

Another important factor that might be overlooked is the rationale for the "map wind" technique. The objective is to increase the scale of measurement so that the map values are more closely allied to the wind sensed by the shell. This implies that a good deal of smoothing should be applied to eliminate those small-scale eddies that are not significant to the shell's trajectory. For this reason, the isotachs should present broad, smooth contours, free from abrupt changes in curvature or "bulls' eyes" due to data at one station. The latter should be viewed with suspicion and rarely accepted. One great advantage of the map wind technique is the possibility of eliminating spurious data by relating it to values at neighboring points. Forcing the isotachs to conform to every station, regardless of the wind values, defeats the basic concept of a map wind, and reduces the chart to a mere pictorial presentation of single station data.

With these considerations in mind, the maps for 25 January 1965 were analyzed, considering carefully the values of the wind components at the station locations.

Because of time limitations, maps for displaced stations were not drawn. At any rate, the fixed station map must be drawn first to determine which stations are to be used and which are not. After this map is completed, it would seem more logical to select, from the map, appropriate values for the fixed locations. These values should be displaced in the direction of the mean wind. For the series of maps illustrated, the displacement of the balloon from the observing point when it has reached 7,000 m (the midpoint of zone 10) is used to determine the new coordinates for the wind values. It should be emphasized that displacing a spurious wind value compounds the error. Not only is the uncovered magnitude of the wind propagated, but the displacement distance is in error as well. Thus, extreme care must be taken when constructing a map for displaced stations so that additional errors are not introduced into the analysis.

This concept of constructing a displaced station map is not a simple one. Actually, the map represents the conditions that exist when the balloon has reached the midpoint of the zone. In other words, the valid map time is not release time, but somewhat later. In the case of zone 10, it is almost 30 minutes later. To obtain a picture of conditions at balloon launch, one would displace the wind values up-stream and plot a new map. The validity of these maps depends on the validity of Taylor's Hypothesis, which is difficult to confirm for the type of problem involved here. In the last analysis, the validity of any map is the ability of the parameter values to correct the artillery firings so that the shell hits the intended target. Thus, the form of ballistic message that consistently reduces the residual mass distance to a minimum is the preferred one.

A.2 Ballistic Wind Maps

Ballistic wind maps for 25 January 1965, line 10, were constructed for each of the balloon release times. It will be noted that there are some differences from those presented in Figs. 2-2 through 2-6, as discussed above. Plotted above each station is the zonal component of the ballistic wind, Vx; while Vy, the meridional component, is plotted below. The isotachs with large positive values are Vx, the negative ones are isolines of Vy. The ballistic wind for line 10 is plotted as a large arrow through the station.

The main feature of the maps is a maximum of Vx that appears centered at 0600 between Ft. Huachuca and Bisbee. The center moves eastward during the morning with the center east of Douglas on the 1400 map. The Vy component is much smaller, but an area of maximum northerly ballistic winds appears almost stationary from 0800 through 1400 in the extreme eastern part of the map between Wilcox and Douglas.

The isotachs on the maps were subjected to considerable smoothing to eliminate small-scale eddies and increase the scale of measurement. In the process of smoothing, several station measurements were discarded as being unrepresentative or in error. A brief discussion of these follows:

0800 Map

Hereford—Measured ballistic wind value is too small. Note Parker Canyon wind and Bisbee wind, 89 knots and 96 knots, respectively. Hereford should be between these two values. It might be argued that Bisbee is too large. Compare, however, 0600 values, Parker Canyon and Bisbee, 88 knots and 97 knots, respectively, with corresponding 0800 values. Since these correspond quite well, Hereford was discarded.

Fairbanks—Absolute value of Vy appears much too small in comparison with Sonoita and Tombstone. The meridional component of the latter is likewise low. Drawing for it would cause sharp inflection points and an unrealistic gradient. Thus, the Vy components of Fairbanks and Tombstone were discarded also.

1000 Map

Hereford—Completely wrong; similar reasoning to that of the 0800 map.

Fairbanks—Magnitudes of both Vx and Vy are too low.

Tombstone—Magnitude of Vy too low.

1200 and 1400 Maps

Both components of the winds at Hereford and Fairbanks are incorrect.

The values of the ballistic wind to be used for stripping are listed in the table below

BALLISTIC WINDS ALONG THE TRAJECTORY

Time (MST)	Vx(knots)	Vy(knots)
0600	91	- 8.5
0800	84	-16.5
1000	85	-21.5
1200	75	-23.0
1400	68	-20.0

These values will be used to correct for non-standard conditions and will be compared with values obtained from the other maps in this report and single station measurements. There appears to be a decrease in Vx with time and an increase in Vy from Table 2-1, although there are some irregularities. Which values are in error will be determined when stripping is completed and the values inserted in the computer program.

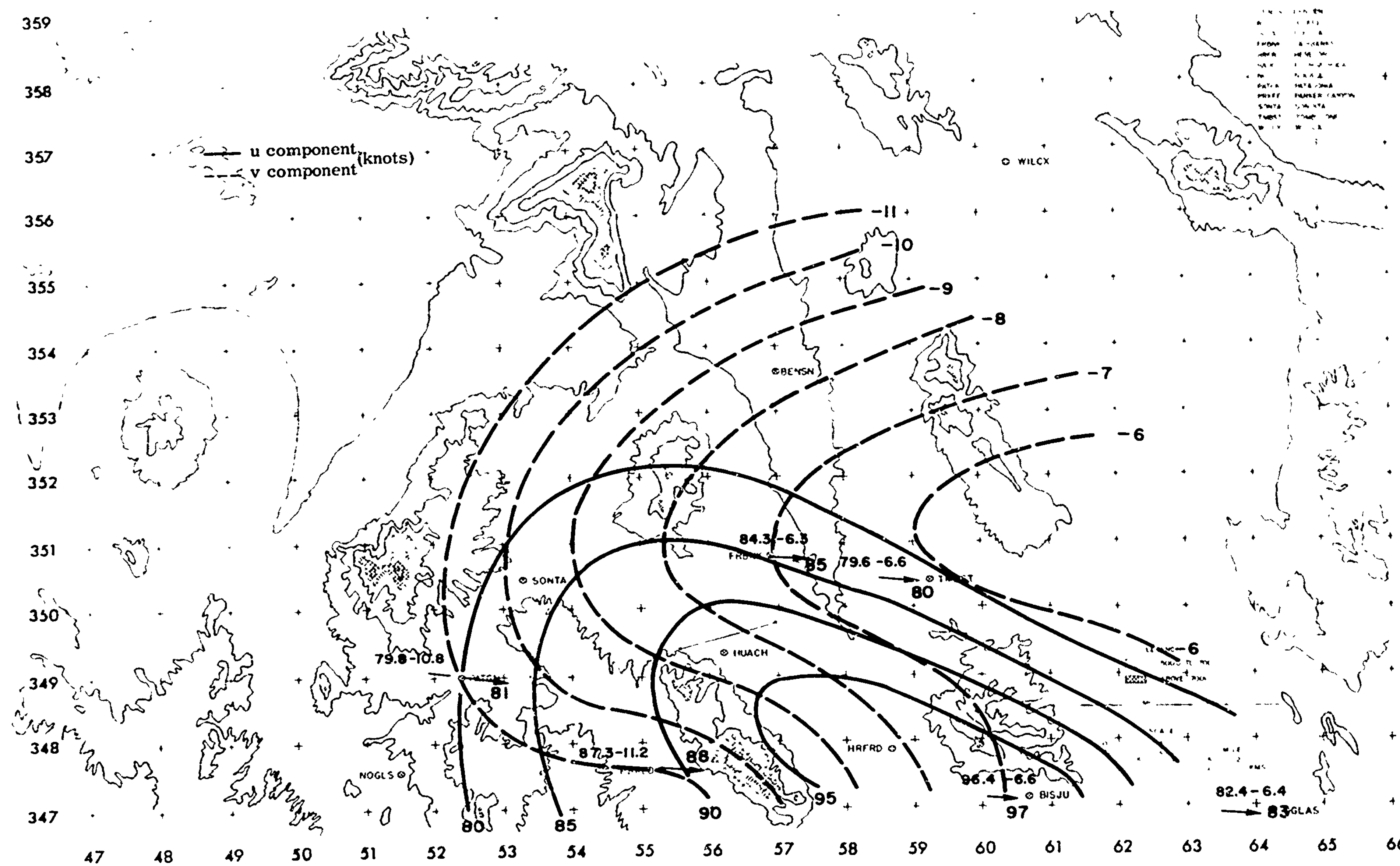

Fig. A-1. Ballistic wind map, line 10, 0600 LST, 25 January, 1965.

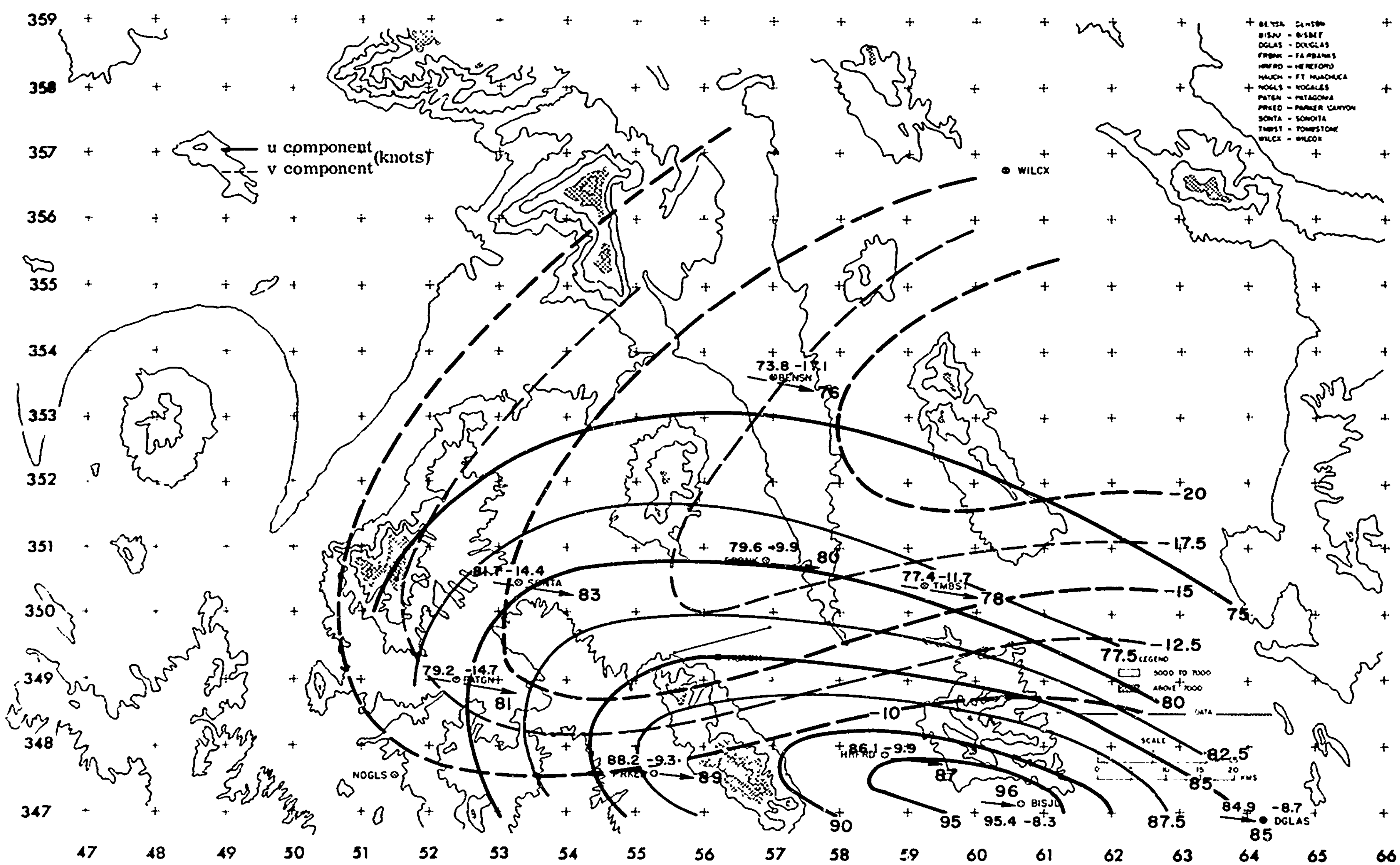

Fig. A-2. Ballistic wind map, line 10, 0800 LST, 25 January, 1965.

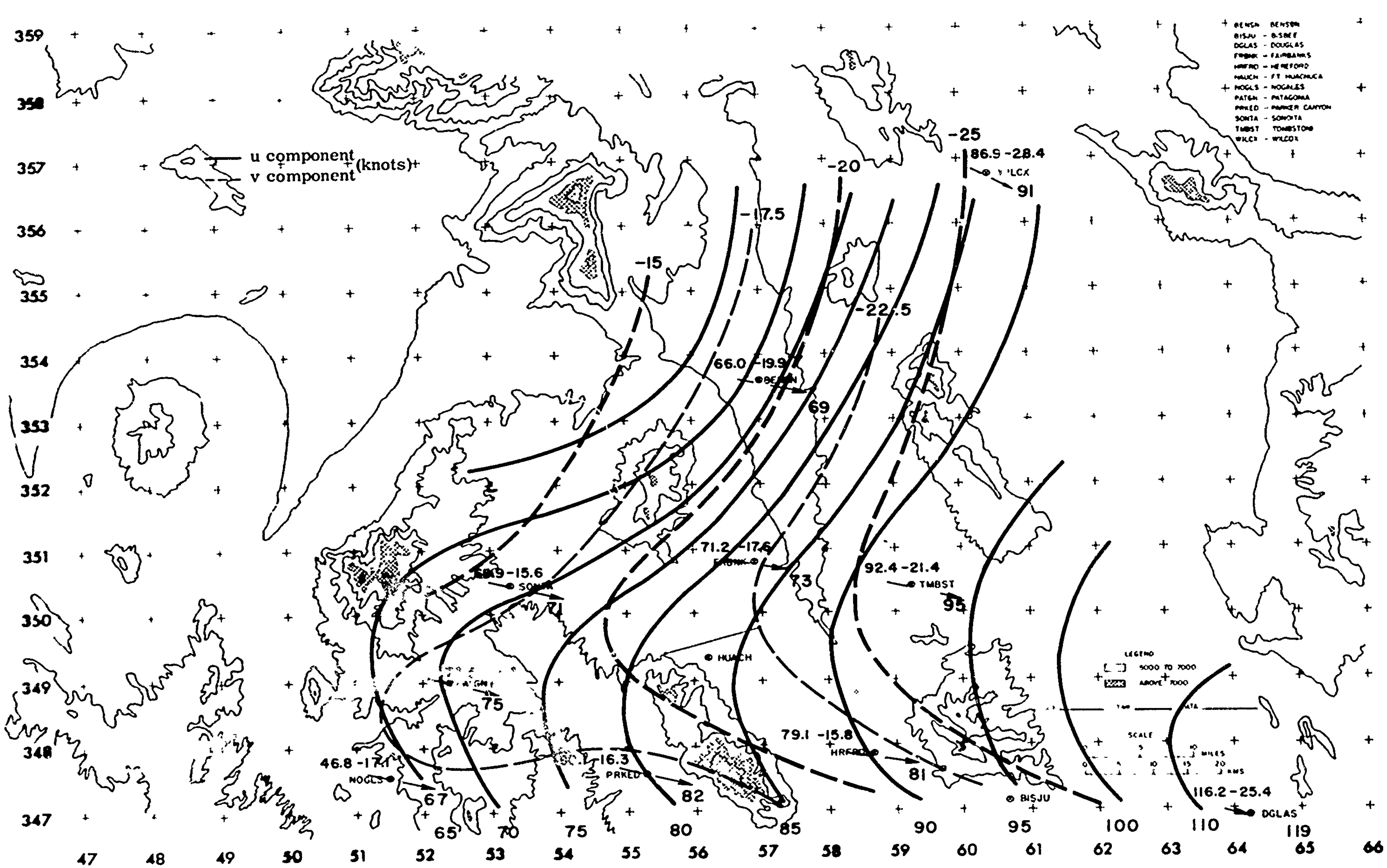

Fig. A-3. Ballistic wind map, line 10, 1000 LST, 25 January, 1965.

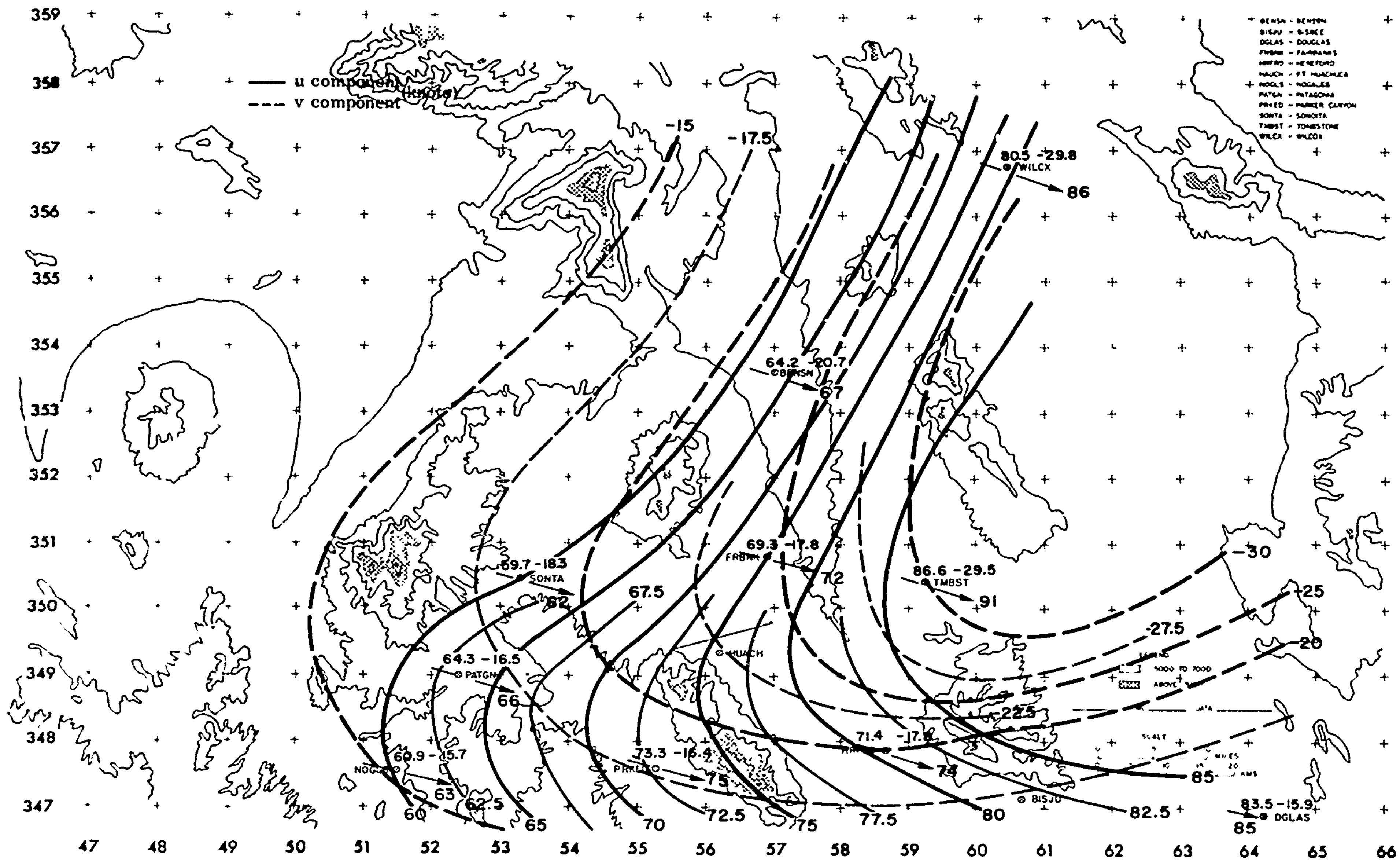

Fig. A-4. Ballistic wind map, line 10, 1200 LST, 25 January, 1965.

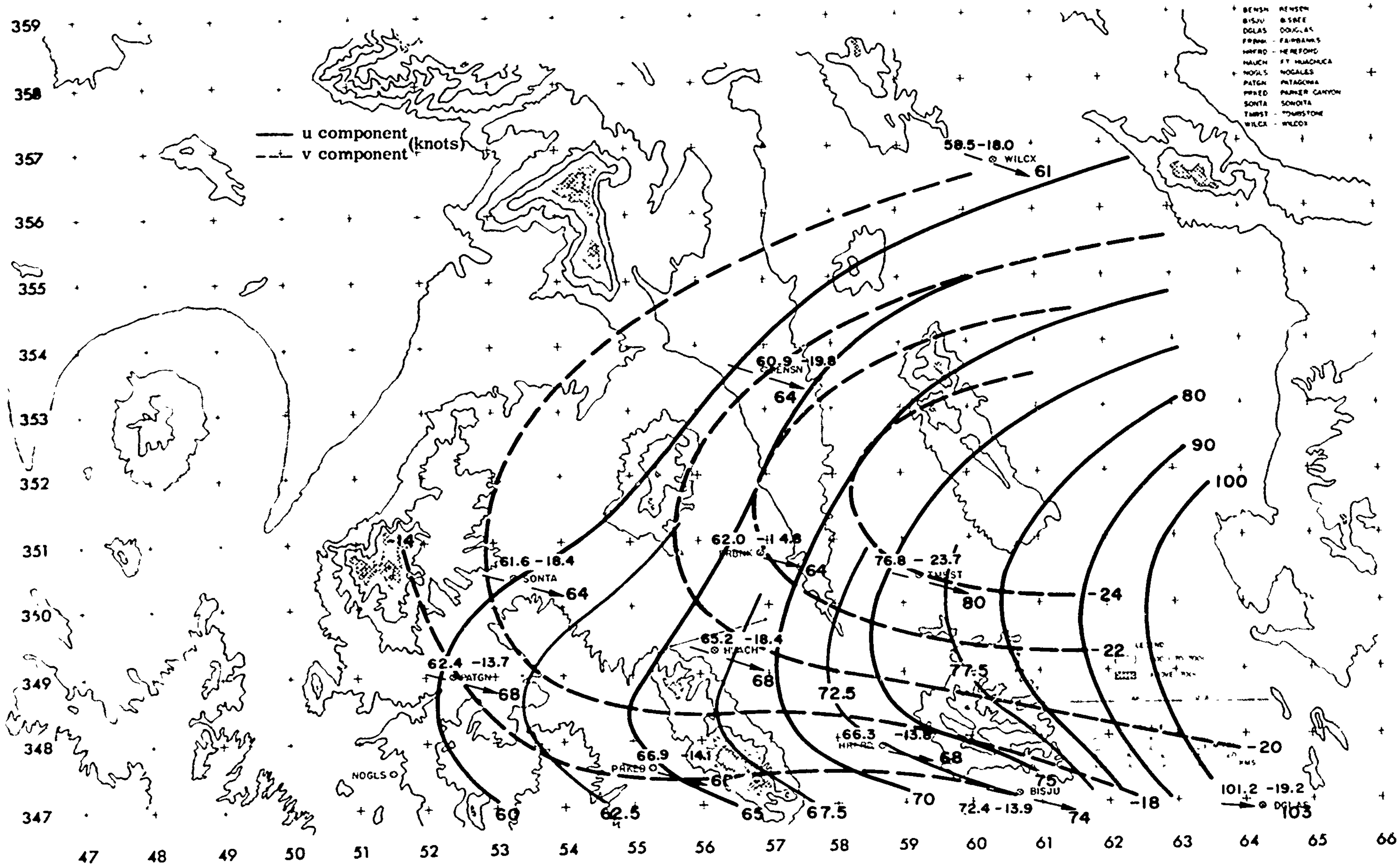

Fig. A-5. Ballistic wind map, line 10, 1400 LST, 25 January, 1965.

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13. ABSTRACT

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